



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Asad M. Madni, *et al.*
Serial No.: 09/904,067
Filed: July 11, 2001
For: DIFFERENTIAL
CAPACITIVE TORQUE
SENSOR
Art Unit: 3617
Examiner: Octavia Davis

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Docket No: 09081-0005

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11/13/03
Linda Clinkenbeard

RESPONSE AFTER FINAL REJECTION

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This response is submitted in response to the Final Rejection dated August 26, 2003. The Applicants wish to thank the granting of the personal interview that took place on Thursday, November 6, 2002 between Examiner Davis and Primary Examiner Noori and Dr. Vuong, one of the joint inventors of the subject application, and the undersigned attorney.

After the interview, Examiner Davis prepared the Interview Summary that is part of this record. Examiner Davis added the following summary of this interview:

“Applicant pointed out the differences between the references and the invention as claimed. Applicant’s demonstration better clarified the invention. Examiner will review Applicant’s response in view of the discussion. It appears that the references applied do not read on the claims.”

Prior to the interview, claims 1- 8 had been rejected under 35 U.S.C. 103(a) as
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being unpatentable over Montagu *et al.* (6,218,803) in view of Kovacich *et al.* (6,442,812) and Takahashi (4,244,219).

During the interview, it was emphasized how Montagu *et al.* do not disclose nor suggest such a cage of conductive material. The differential capacitive sensor disclosed by Montagu *et al.* starting at col 6, line 1 and shown in FIGS. 1 and 2 does not serve the same function as the Applicants' sensor since Montagu *et al.* disclose only a narrow angle sensor. Because of the orientation of the elements making up the Montagu *et al.* sensor, only angles of less than 90 degrees can be measured; see FIG. 2 of Montagu *et al.* The Montagu *et al.* sensor does not measure nor is it capable of measuring the torque of a steering shaft with a torsion bar embedded in the shaft to divide it into first and second halves as in the Applicants' sensor that performs an angle measurement simultaneously with the rotation of the shaft.

The importance of dividing the shaft into two halves was emphasized during the interview. It was pointed out that there are presently no sensors except the Applicants' sensor that is designed for a shaft divided into two halves. There is no suggestion in Montagu *et al.* nor in any other reference of dividing shaft 9 into first and second halves having a torsion bar buried therein.

During the interview it was explained how the capacitive plate members 1, 2, 3, and 4, which are mounted on a stationary support plate 14 of Montagu *et al.* are not equivalent to nor function in the same manner as the pair of concentric capacitor plate rings (12 & 13) where one ring (13) has a greater diameter than the other ring (12) as in the Applicants' sensor.

During the interview, it was discussed that Kovacich *et al.* disclose and claim a piezoelectric torque sensor that is entirely different from the Applicants' differential capacitive torque sensor. The sensor of Kovacich *et al.* is based on crystal oscillator theory as shown by the electrical schematic of their system shown in FIG. 9. The representation of the capacitive portion of the invention claimed in this reference is shown on FIGS. 6 and 7. These figures clearly demonstrate that this design has no utility in detecting changes in capacity for small angles of differential rotation while maintaining that capacity, at a constant torque, through infinite revolutions of the shaft as the Applicants sensor is designed to accomplish. This is true because the differential angle that is created by the torsion member of the Kovacich *et al.* is considerably less than one tenth of a degree. Comparing the torque sensor shown in FIGS. 6 and

7 of Kovacich *et al.* with the Applicants' FIG. 11, the Examiners present during the interview were able to appreciate that one skilled in the art would not be able to combine anything disclosed in this reference with that disclosed in the Montague *et al.* reference to come up with the Applicants' differential capacitive torque sensor.

The Examiners present during the interview recognized that the first and second cylindrical electrode layers 142 and 144 that are respectively mounted on circular plates 144 and 148 neither have any similarity nor function in a manner similar to that of the Applicants' pair of first and second apertured conductive disks.

It was also shown during the interview that while Takahashi's disc members 23₁ and 23₂ having apertures 23₄ and 23₅ have some similarity to the Applicants' apertured conductive disks; Takahashi's invention is directed to a single variable capacitor as a detection element for the torque measurement. It was clearly demonstrated that the Takahashi invention is not even remotely based on the differential technique of the Applicants' claimed invention.

The Applicants sensor converts the differential angle between the first and second halves of the shaft that is the result of the applied torque to the torsion bar embedded into the shaft, not disclosed in any of the cited references, to a rotational movement of the dielectric element. This is shown in the Applicants' FIGS. 5-9. This was also demonstrated by means of a prototype of the Applicants' claimed sensor.

FIG. 8 shows the Applicants' sensor is set to nominal with spokes 17 of dielectric disk 16 being half-way into the inner aperture of inner aperture ring 22 and half-way into the outer aperture of outer aperture ring 21 of apertured conductive disks 18 and 19. When this occurs, the Applicants' sensor is balanced and the output is in the mid range. Thus, this will provide equal values or balanced capacitances, C1 and C2, because of the equal areas of the concentric plate rings 12 and 13. The rotational movement of the first apertured conductive disk 18, caging the dielectric disk 16 with respect to the second apertured conductive disk 19, causes the change of capacitance of one of the capacitor plate rings, e.g. 12, to increase as the other ring, e.g. 13, decreases proportionately.

FIG. 9 illustrates a maximum torque situation (for one rotational direction), where the inner apertures are only minimally covered by spokes 17 and the outer apertures are provided with maximum coverage by spokes 17. The cage of conductive disks 18 and 19 serves to shield

spokes 17 from the opposed capacitor plates (see FIG. 2) and will have no influence on the capacities C1 and C2. Thus, the capacities are modified as the spokes move out of the confines of the shielded portion of the cage and into the apertures of the cage. FIG. 9 shows the outer ring 13 having the maximum capacity because the dielectric spokes 17 are substantially unshielded and the inner ring 12 having the minimum capacity because it is substantially shielded.

The Applicants' invention not only satisfies the basic variable capacitor equation, but also results in a ratiometric output. The Applicants' invention is a completely non-contacting design. Unlike other similar sensors in the prior art, the Applicants' sensor has no slip-rings or ribbon cable for power or signal, that should mean that it has unlimited life. The output of the Applicants' sensor can be computed by the equation $(C1-C2)/(C1+C2)$ where the capacitance C1 occurs between plate opposed capacitor 10 and the outer concentric ring 21 and the capacitance C2 occurs between the plate 10 and the inner concentric ring 22. The output of this sensor is proportional to the change in angle between the first and second halves of the shafts as a result of applied torque on the shafts.

During the interview, it was emphasized that the output signal is also stable through changes in temperature, humidity and other environment changes due to the ratiometric structure and inherent common mode rejection of the two annular capacitive rings. The Applicants' sensor also provides a constant output when a fixed torque is applied to the shafts and both shafts rotate through multiple 360° degree turns along the center axis.

Finally, it was shown during the interview that claim 1, the only independent claim in the case, adequately defines each and every element that exists in the working prototype that was displayed.